

1. (Amended) A method for controlling the simulated interfacing of a first body controlled by a user with a second body, while providing haptic feedback to the user on such interfacing including:

storing selected representations of said first body and of said second body in a processing apparatus, the representation for one of said bodies being an implicit representation and the representation for the other body being a discrete representation;

B1 using a user controlled interface device to control simulated movement of the first body relative to the second body;

detecting any collision between the first body and the second body, including the position on each body of each collision, the direction of the collision, and force for the collision;

converting the detected direction, point and force for each collision into at least one force vector on the first body; and

applying said at least one force vector as a corresponding feedback force vector to said interface device, and thus to the user.

4. (Amended) A method as claimed in claim 1 wherein said first body representation is a binary space partition tree representation.

B2 5. (Amended) A method as claimed in claim 1 wherein force for a collision is represented at least in part by penetration of the body represented by the implicit representation into the other body.

6. (Amended) A method as claimed in claim 1 wherein said discrete representation is a point cloud representation of the body.

B3 20 (Amended) A method as claimed in claim 17 including defining a snap-fit region for said tool around each working surface wherein contact with the second body is desired.

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cont 26. (Amended) A system for controlling the simulated interfacing of a first body controlled by a user with a second body, while providing haptic feedback to the user on such interface including:

at least one memory storing selected representations of said first body and of said second body, the representation for one of said bodies being an implicit representation and the representation for the other body being a discrete representation;

a user controlled hepatic interface device; and

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could* processing apparatus responsive to said interface device for providing simulated movement of the first body relative to the second body, said processing apparatus detecting collisions between the bodies resulting from such simulated movement, including the position on each body of each collision, the direction of the collision, and force for the collision, converting the detected direction, point and force for each collision into at least one force vector and, feeding back the at least one force vector through said interface device.

B5 29. (Amended) A system as claimed in claim 26 wherein said first body representation is stored as a binary space partition tree representation.

30. (Amended) A system as claimed in claim 26, wherein force for a collision is represented at least in part by penetration of the body represented by the implicit representation into the other body.

Please add the following new claims.

35. (New) A method of providing haptic feedback corresponding to full-body contact between a first object controlled by an interface device and at least one second object, the method comprising acts of:

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omit* storing a first three dimensional representation and a second three dimensional representation of the first object and the at least one second objects, respectively, wherein one of the representations includes at least one region defined by a implicit equation and the other representation includes a point cloud.

determining presence or absence of penetration of the first and second representations at each point in the point cloud;

computing a vector having a magnitude related to depth of the penetration and a direction related to direction of penetration of each penetration;

computing at least one force vector corresponding to the full-body contact between the first and second object based on at least one of the penetration vectors.

36. (New) The method of claim 35, wherein the act of forming the point cloud representation includes an act of forming a bounding volume hierarchy of the point cloud representation and wherein the act of determining a presence or an absence of a penetration includes an act of traversing the bounding volume hierarchy, each successive determination of a presence or an absence of a penetration involving portions of the bounding volume for which the presence of a penetration was determined.

37. (New) The method of claim 35, wherein a binary space partition tree is associated with the implicit equation representation and wherein the act of determining a presence or an absence of a penetration includes traversing the binary space partition tree.

38. (New) The method of claim 39, wherein determining a presence or an absence of a penetration includes intersecting iteratively refined portions of the binary space partition tree and the boundary volume hierarchy.

39. (New) The method of claim 35, wherein at least some of the points in the point cloud representation are vertices in a triangulated surface.

40. (New) The method of claim 35, wherein the first three dimensional representation is of the first object and the at least one region includes a plurality of regions defined by a plurality of implicit equations, at least one region having associated with it a niceness factor related to the desirability of contact between the at least one region and the second object.

41. (New) The method of claim 35, wherein the first three dimensional representation is of the first object and the at least one region includes a plurality of regions defined by a plurality of implicit equations, and wherein at least one region has associated with it a snap-fit region to urge the first object in a direction to bring the at least one region in contact with the second object when the second object is within the snap-fit region.

42. (New) The method of claim 35, wherein the second three dimensional representation is of the at least one second object and wherein the second three dimensional representation has associated with it a snap-fit region to urge the first object in a direction to bring the first object in contact with the second object when the first object is within the snap-fit region.

43. (New) In a virtual three-dimensional environment including a haptic interface device to control a simulated movement of at least one first object with at least five degrees of freedom with respect to at least one static object, the at least one first object represented by one or more geometric regions, a method of generating a posture map of the moveable object, the method comprising acts of:

storing a posture of the moveable object at least at points at which the at least one first object has a posture wherein a portion of at least one region penetrates the at least one static object; and

determining the posture being stored based on at least one of a niceness factor associated with the one or more regions penetrating the at least one static object, and a depth of the penetration of the one or more regions.

44. (New) The method of claim 43, wherein determining the posture being stored includes choosing the posture having the highest niceness factor associated with the one or more penetrating regions.

45. (New) The method of claim 43, wherein determining the posture being stored includes an act of choosing a posture only when a niceness factor associated with the one or more penetrating regions exceeds a predetermined threshold.

46. (New) The method of claim 43, wherein determining the posture being stored includes an act of determining the posture being stored based on a niceness factor associated with the one or more regions penetrating the at least one static object, and a depth of the penetration of the one or more regions.

47. (New) A posture map for generating guide paths for at least one first object, the posture map comprising:

a set of three-dimensional points in a virtual three-dimensional cartesian space, each three-dimensional point having associated with it a posture, each posture including:

a first, a second, and a third location component representing a reference coordinate location of the at least one first object with respect to a first, a second, and a third axis of the cartesian space, respectively; and

a first and a second rotation angle representing a rotation of the at least one first object about the first and second axis, respectively.

48. (New) The posture map of claim 47, wherein the set of three-dimensional points are the points in the virtual three-dimensional space where at least one portion of a first representation of the at least one first object in the three-dimensional space penetrates a representation of at least one second object in the three-dimensional space.

49. (New) The posture map of claim 48, wherein the first representation is divided into a plurality of regions, each of the plurality of regions having associated with it a niceness factor indicating the desirability of penetration between the region and the at least one second object.

50. (New) The posture map of claim 49, wherein the posture at each point in the set of three-dimensional points corresponds to a desired posture of the at least one first object and wherein the posture is chosen based on at least one of a niceness factor associated with at least one penetrating region, and a depth of the penetration of the at least one penetrating region.

51. (New) The posture map of claim 49, wherein the posture at each point in the set of three-dimensional points is chosen based on the niceness factor associated with the at least one penetrating region, and a depth of the penetration of the at least one penetrating region.

52. (New) A method of providing haptic feedback to a user corresponding to simulated movement of a first object in a desired relationship with respect to at least one static object, the simulated movement of the first object controlled by a haptic interface device, the method comprising acts of:

simulating the movement of the first object in correspondence to movement of the haptic interface device;

providing haptic feedback to the user by providing a correction force to the haptic interface device computed based on at least one of a posture map of the first object and at least one guide zone.

53. (New) The method of claim 52 wherein the haptic interface device is capable of movement and the first object is capable of simulated movement with at least five degrees of freedom.

54. (New) The method of claim 52, wherein the act of providing a correction force to the haptic interface device includes an act of computing at least one force vector based on each penetration between a first representation of the first object and a second representation of the at least one static objects.

55. (New) The method of claim 54, wherein the at least one force vector is computed from a location, a direction, and a depth of penetration of each penetration.

56. (New) The method of claim 54, wherein the first object includes at least one guide zone and the act of providing a correction force includes computing the at least one force vector based on a force in a direction that urges the moveable object towards a portion of the at least one static object when the portion is within at least one of the at least one guide zone.

57. (New) The method of claim 54, wherein the at least one static object includes at least one static part and a plurality of layers associated with the at least one static part and the act of providing a correction force includes computing the at least one force vector based on each

penetration between the representation of the first object and a plurality of constraint planes associated with the plurality of layers.

58. (New) The method of claim 57 wherein the plurality of constraint planes include a respective plurality of guide zones and the act of providing a correction force includes computing the at least one force vector based on a force in a direction that urges the first object towards a constraint plane when a portion of the representation of the first object is within a guide zone of the constraint plane.

59. (New) The method of claim 57 wherein the part includes at least one guide zone and the act of providing a correction force includes computing the at least one force vector based on a force in a direction that urges the first object towards the part when a portion of the representation of the first object is within at least one guide zone.

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60. (New) The method of claim 52 wherein providing the correction force includes computing at least one force vector that urges a posture of the first object at a given point to change so as to reduce a difference between the posture of the first object and a posture stored in the posture map at the given point.

61. (New) The method of claim 60, wherein each posture in the posture map includes a first, a second, and a third location component indicating a desired position of the first object, and a first and a second rotation component indicating a desired rotation.

62. (New) An apparatus for controlling the simulated movement of a first object in a desired relation to at least one second object, the apparatus comprising:
a haptic interface for controlling simulated movement of the first object;
a first representation of the first object stored in memory;
at least one second representation of the at least one second object stored in memory;
at least one of a posture map and a guide zone to urge the simulated movement of the first object in a desired relationship with the at least one second object.

63. (New) The apparatus of claim 62, wherein the haptic interface is capable of movement with at least five degrees of freedom, and the movement of the first representation of the first object is simulated with at least five degrees of freedom.

64. (New) The apparatus of claim 62 including the at least one posture map, wherein each posture in the at least one posture map includes a first, a second, and a third location component indicating a desired position of the first object, and a first and a second rotation component indicating a desired rotation of the first object.

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65. (New) The apparatus of claim 62, including at least one guide zone associated with at least one of the first object, and the at least one second object.

66. (New) The apparatus of claim 62, including a posture map and at least one guide zone.
